# Aggregation of Hyperion Hyperspectral Spectral Bands into Landsat-7 ETM+ Spectral Bands

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***Abstract* – The Landsat 7 ETM+ spectral bands centered at 479nm, 561 nm, 661 nm and 834 nm (Bands 1, 2, 3, and 4) fall nicely across the Hyperion VNIR hyperspectral response region. They have bandwidths of 67nm, 78nm, 60 nm and 120 nm, respectively. The Hyperion spectral bandwidth of 10.2 nm results in 10 to 15 Hyperion spectral samples across each Landsat band in the VNIR. When the Hyperion spectral responses in the 10.2 nm bands are properly weighted to aggregate to a given Landsat band, the radiometric response of the Landsat band can be reproduced by Hyperion. This is done for Bands 2, 3 and 4 on the scene 7 of Lake Frome, Australia collected simultaneously by Hyperion and Landsat on January 21, 2001. The initial comparison of the radiances from Hyperion synthesized into the ETM+ bands with the Landsat-7 ETM+ radiances showed differences of 15-23%, with ETM+ being higher. Prior to launch a laboratory standard comparison showed differences of 10-13% in the same direction.**

## I. INTRODUCTION

EO-1 and Landsat-7 are currently flying in formation with about a 1 minute difference in overpass time. Hyperion, a hyperspectral imaging spectrometer covering the spectral range of 400-2400 nm with a spectral resolution of 10 nm is one of the sensors on EO-1. Spatial resolution is 30 meters. ETM+ is the only sensor on Landsat-7 and has six 30 meter resolution bands covering the range of 450 to 2350 nm with bandwidths varying from 60 – 270 nm.

The objective of this analysis is to compare the radiometric calibration of Hyperion to that of the Landsat-7 ETM+ instrument. Results to date cover only ETM+ bands 2, 3 and 4, 561 nm, 661 nm and 834 nm band centers, respectively, as these bands are covered well by the Hyperion VNIR hyperspectral array. Each ETM+ band of 60 –120 nm bandwidth is covered by 6-7 Hyperion bands of about 10 nm bandwidth.

During June 1999, the Landsat transfer radiometer that is used for calibrating the secondary standard integrating sphere was brought to TRW for cross-calibration with the Hyperion calibration panel assembly secondary radiance standard. This paper discusses the calculation of the weights applied to each Hyperion spectral pixel for aggregation into a given ETM+ 7 band and the results of the radiance measurements for a scene at Lake Frome. Comparison is made with the ground calibration results as well. The absolute ground calibration of Hyperion is discussed by Jarecke [1]. Other papers related to these results are presented at this conference; a paper on solar calibration of Hyperion is in the Hyperspectral Applications Session (C27BTU paper NO. 1777) and a paper on the vicarious calibration using a ground truth campaign related to this January 21, 2001 data collection is in Special Session 40. SS40MO, paper 1780.

## II. AGREGATION OF HYPERION SPECTRAL CHANNELS INTO THE LANDSAT 7 BANDS

The normalized bandwidth , BW (i) total integrated wavelength of a spectral band, i, is given by

$$BW(i) = \int_{\lambda} f(\lambda) d\lambda \qquad \text{eq. 1}$$

where f (λ) is the relative spectral response function of the band integrated over the spectral region of response. When the integral is weighted by wavelength and normalized by the bandwidth, the result is usually referred to as the effective wavelength of the band.

$$\lambda_{eff} = \frac{\int_{\lambda} \lambda f(\lambda) d\lambda}{\int_{\lambda} f(\lambda) d\lambda} \qquad \text{eq. 2}$$

Consider Landsat 7 – Band 3 as an example for binning. This band is covered by Hyperion pixel number 27 (619.1 nm) through number 36 (710.8 nm). The response of these pixels cannot be summed directly to reproduce the Landsat band but must be weighted to account for the relative spectral throughput of the Landsat band at that spectral position. The spectral response of each channel of Hyperion is very close to a gaussian in shape with a width at the 50 % relative response point of 10.19 nm. The value of 10.19 nm comes from the spectral width of the pixel; so the integrated bandwidth of the Hyperion channel must be given by a rectangle normalized to 1.0 and with a width that is equal to the spectral spacing of the adjacent channels (10.19 nm). Hence, the gaussian function must be normalized to assure than the integral of $g(\lambda)$ over wavelength gives an integrated bandwidth of 10.19 nm.

The weight to apply to a given pixel for binning is given by

$$\mathrm{Wgt}(i) = \int_{\lambda} g(\lambda) f(\lambda) d\lambda \qquad \text{eq. 3}$$

If the weights are properly normalized, the sum of the weights must equal the effective bandwidth of the Landsat 7 band. Table I shows the weights for Bands 2, 3 and 4 used in this analysis for each Hyperion spatial pixel and its center wavelength. The sum of the weights is given at the bottom of the column of weights. The differences between the Landsat integrated bandwidth and the sum of the weights is less than 0.1% indicating the normalization is correct.

TABLE I.

HYPERION PIXEL NUMBERS, CENTER WAVELENGTHS AND WEIGHTS FOR EACH LANDSAT BAND

| **Band 2** | | | **Band 3** | | | **Band 4** | | |
|---|---|---|---|---|---|---|---|---|
| Pixel No. | WL [nm] | WGT [nm] | Pixel No. | WL [nm] | WGT [nm] | Pixel No. | WL [nm] | WGT [nm] |
| 16 | 506.9 | 0.27 | 27 | 619.1 | 0.16 | 41 | 761.8 | 1.31 |
| 17 | 517.1 | 3.52 | 28 | 629.3 | 4.08 | 42 | 772.0 | 5.34 |
| 18 | 527.3 | 7.85 | 29 | 639.5 | 9.31 | 43 | 782.2 | 8.86 |
| 19 | 537.5 | 9.35 | 30 | 649.7 | 9.81 | 44 | 792.4 | 9.43 |
| 20 | 547.7 | 9.70 | 31 | 659.9 | 9.88 | 45 | 802.6 | 9.41 |
| 21 | 557.9 | 9.73 | 32 | 670.0 | 10.13 | 46 | 812.8 | 9.31 |
| 22 | 568.1 | 9.63 | 33 | 680.2 | 9.79 | 47 | 823.0 | 9.75 |
| 23 | 578.3 | 9.86 | 34 | 690.4 | 6.16 | 48 | 833.2 | 9.82 |
| 24 | 588.5 | 9.74 | 35 | 700.7 | 0.63 | 49 | 843.4 | 9.56 |
| 25 | 598.7 | 6.54 | 36 | 710.9 | 0.01 | 50 | 853.6 | 9.87 |
| 26 | 608.9 | 1.23 | | | | 51 | 863.8 | 10.13 |
| 27 | 619.1 | 0.12 | | | | 52 | 874.0 | 10.08 |
| | | | | | | 53 | 884.2 | 9.09 |
| | | | | | | 54 | 894.4 | 7.21 |
| | | | | | | 55 | 904.6 | 1.21 |
| | | | | | | | | |
| | | 77.52 | | | 59.97 | | | 120.40 |

Even though the Hyperion spectral response resolution is better than the Landsat 7 band, (i.e. it breaks up the same variable scene spectrum for measurement into ~ 10 individual bands), the final radiometric measure of the scene is the same. This is because the summation of the individual weighted Hyperion responses mirrors in a digital way the analog summation that the Landsat 7 band performs with its automatic weighting of the scene spectrum which for band i equals the BW(i), the bandwidth. The result of the Hyperion summation creates an in-band radiance measurement in units of W/m2-sr. The Landsat 7 data set produces a spectral radiance in units of W/m2-sr-um as the value of the scene radiance near the effective wavelength ( depending on the details of the scene spectral radiance). To convert the Hyperion in-band radiance to spectral radiance the result is divided by the bandwidth BW.

## II. LAKE FROME RADIANCE COMPARISONS

The Landsat data file of Lake Frome on January 21, 2001 was level 1G radiance data which is radiometrically corrected and geo-rectified with nearest neighbor resampling. Two spatially uniform regions of Lake Frome were selected and overlapping data from the Landsat image and weighted data from the Hyperion image were saved in a file and compared. One region was relative bright and the other dark. The results at each band agreed to within a 1% difference.

Table II lists the percentage differences of radiances of the average of the two Lake Frome sites (positive means Landsat 7 measured larger radiances). Also listed in the table are the comparisons between the secondary calibration standards (the Landsat 7 transfer radiometer and the Hyperion calibration panel assembly). The comparison between standards was carried out twice in June 1999, once during acceptance tests of Hyperion at TRW and again, a week later, at NASA/GSFC.

TABLE II

COMPARISON OF GROUND CALIBRATION STANDARDS AND THE ON-ORBIT COMPARISONS OF LANDSAT 7 BANDS 2, 3 AND 4 AND HYPERION BAND AGGREGATED RADIANCES.

| | Effective Wavelength | Ground Comparison | On-Orbit Comparison |
|---|---|---|---|
| Band 2 | 561 nm | 9.9% | 1.8% |
| Band 3 | 661 nm | 11.0% | 2.4% |
| Band 4 | 834 nm | 12.7% | 10.1% |

## III. CONCLUSIONS

The results in Table II are preliminary. Additional comparisons from Lake Frome and from other sites will help derive and verify the on-orbit differences. Understanding them further will come from independent data; comparison with other instruments including the Advanced Landsat Imager (ALI) which is on the EO-1 spacecraft, solar calibration data and ground truth campaigns such as those discussed in the other papers in this conference cited in the introduction.

## REFERENCES


[1] P. Jarecke, K. Yokoyama, "Radiometric Calibration of the Hyperion Imaging Spectrometer Instrument From Primary Standards to End-to-End Calibration" ", *Proc. of SPIE*, Vol. 4135, pp 254-263, July 2000.